PENNSYLVANIA STATE LIBRARY
DOCUMENTS SECTION

PROGRESS REPORT 152
PENNSYLVANIA GEOLOGICAL SURVEY
FOURTH SERIES

PRELIMINARY REPORT
on the
SEDIMENTARY URANIUM OCCURRENCES
in the
STATE OF PENNSYLVANIA

By
John F. McCauley

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF INTERNAL AFFAIRS
GENEVIEVE BLATT, *Secretary*
TOPOGRAPHIC AND GEOLOGIC SURVEY
CARLYLE GRAY, *State Geologist*
1957

038.12
P4

Errata

e 9, line 4: For "Plate 1" read "Plate 1A"
e 11, line 19: For Plates 2 and 3" read "Plate 1B and Plate 2A"
e 11, line 30: For "Plate 4" read "Plate 2B"
e 11, line 35: For "Plate 5" read "Plate 3A"
e 14, lines 2 and 6: For "Plate 6" read "Plate 3B"

Digitized by the Internet Archive
in 2016 with funding from
This project is made possible by a grant from the Institute of Museum and Library Services as administered by the Pennsylvania Department of Education through the Office of Commonwealth Libraries

https://archive.org/details/preliminaryrepor00mcca_0

FOREWORD

Uranium occurrences in Pennsylvania are of widespread and deep interest to many persons, as is demonstrated by the steady stream of visitors, letters, or telephone calls to our Bureau of Topographic and Geologic Survey concerning this topic. In many instances, the inquiry is accompanied by samples and the request that the sender be informed if they contain uranium and whether or not they possess economic value. Progress Report 152 has been prepared in the hope that it will be of help to those seeking such information and will be of genuine use to them in their continued prospecting efforts.

As its title indicates, however, this booklet is a "preliminary report" only. There is much more to be done before we know all that is worthwhile to know concerning Pennsylvania's uranium, and we in the Department of Internal Affairs are endeavoring to do as much of that as we can. The writer of this preliminary report, Mr. McCauley, has been working during the summer of 1957 on a more complete study. He has had the benefit of the continued cooperation and association with many prospectors in the field. Using this information, he hopes to complete his doctoral dissertation on this subject for a Ph.D. degree under Dr. Charles H. Behre, Jr., of Columbia University, and the Survey plans to publish the results of his field studies and laboratory analyses late in 1958.

Genevieve Blatt

Genevieve Blatt, Secretary
Department of Internal Affairs

August, 1957

CONTENTS

	Page
PRELIMINARY REPORT ON THE SEDIMENTARY URANIUM OCCURRENCES IN THE STATE OF PENNSYLVANIA	1
INTRODUCTION	1
ACKNOWLEDGEMENTS	1
METHODS	1
LIST OF OCCURRENCES	2
COPPER-URANIUM OCCURRENCES	4
General Setting	4
Stratigraphy	4
General Features of the Occurrences	6
Paleostream Channels	6
Primary Structures	6
Sediments Adjacent to Mineralized Zones	6
Red Sediments Beyond the Mineralized Zones	8
Relation Between Color and Paleostream Channels	8
Description of the Mineralized Zones	9
Distinctive Features	9
Distribution of Radioactivity	9
Mineralogy and Occurrence of Uranium	9
Microscopic Description of the Sulfide Minerals	11
Structural and Stratigraphic Control	14
Other Copper-Uranium Occurrences	15
Summary	15
URANIUM OCCURRENCES (Other than copper associated)	15
General Setting	15
Occurrences in Carbon County	17
Occurrences in Huntingdon County	17
Occurrences in Bucks County	18
Summary	19
GENESIS	20
ECONOMIC POTENTIAL	20
URANIUM ORE GUIDES AND PROSPECTING INFORMATION	20
BIBLIOGRAPHY	22

ILLUSTRATIONS

Figure 1.	Location map of copper-uranium occurrences	5
Figure 2.	Diagrammatic section of Catskill occurrences	7
Figure 3.	Location map of uranium occurrences (other than copper associated)	16
Plate 1 A.	Photograph of a mineralized lens	10
B.	Photomicrograph - galena and carbonaceous material	10
Plate 2 A.	Photomicrograph - galena and carbonaceous material	12
B.	Photomicrograph - cell structures	12
Plate 3 A.	Photomicrograph - cell structures	13
B.	Photomicrograph - chalcopyrite veinlets	13

PRELIMINARY REPORT
on the
SEDIMENTARY URANIUM OCCURRENCES
in the
STATE OF PENNSYLVANIA

By

John F. McCauley

INTRODUCTION

The increasing number of sedimentary uranium occurrences being reported within the state prompted the Pennsylvania Geologic Survey, early in 1956, to undertake a field study to determine their geologic nature and economic possibilities. A total of thirty sedimentary uranium occurrences were examined in July, August, and September of 1956 (see Table 1). Samples were collected and initial studies have been made in the laboratory. This paper represents a preliminary report. It is hoped that an expanded and more complete study will commence in the summer of 1957.

The sedimentary uranium occurrences are found in rocks ranging in age from upper Devonian to Triassic. They have been grouped into two broad categories on the basis of mineralogy. The first group consists of the copper-uranium occurrences. They are characterized by the presence of copper sulfides and carbonates associated with carbonaceous material, in lenses of radioactive rock. No primary or secondary uranium minerals can be detected. The second group comprises those also in radioactive lenses and associated with carbonaceous material, but in which there is no visible copper mineralization. Uranium minerals have been identified from occurrences in this group.

ACKNOWLEDGEMENTS

The thanks of the writer are extended to Dr. Carlyle Gray, Director of the Pennsylvania Geological Survey, who formulated the project and assisted greatly in its execution, and to Dr. Charles H. Behre, Jr., of Columbia University, who supervised the work and contributed many helpful suggestions. Thanks are also extended to Martin Molloy of Columbia University for his aid in the mineralogical work of this report. Much was also contributed by the many prospectors who were invaluable in helping the writer locate the occurrences in the field.

METHODS

The stratigraphic information regarding the relative positions of the various occurrences must be judged in the light of the scope of the project and the methods necessarily employed. The thicknesses given in the text were computed

trigonometrically after measuring the width of the outcrop and obtaining the average dip. The stratigraphic positions within the Catskill formation, given in Figure 2, were determined whenever possible from the base of the Pocono sandstone, the best and most consistent marker in the region. Where this was not feasible, the much less clear contact with the underlying Chemung formation was used. In determining stratigraphic positions, the method was to note the elevations of the nearest contact and of the occurrence, to measure the horizontal distance between them, and to introduce a trigonometric correction for the average dip. These techniques have obvious limitations so that the data given will be subject to re-evaluation in the light of future more detailed work.

The laboratory studies include binocular microscopic description of the sediments, the study of polished sections under the reflecting microscope, spectrographic analysis, and qualitative chemical analysis.

Radioactivity measurements in the field were made with a Detectron Model DG-7 Geiger Counter. A LaRoe scintillometer, Model FV-65 was used in locating many of the occurrences.

TABLE 1

LOCATIONS OF OCCURRENCES EXAMINED*

No.	Type	Formation	Location on Quadrangle Map
1	Cu-U	Catskill	Laporte, R8, .6 mi S47E, Sugarloaf School
2	Cu-U	Catskill	Laporte, R8, .2 mi S63E, Sugarloaf School
3	Cu-U	Catskill	Monroeton, R4, 1.0 mi S71E, Mt. Tabor Church
4	Cu-U	Catskill	Monroeton, R7, 2.0 mi S6W, Mt. Tabor Church
5	U	Pottsville	Mauch Chunk, R4, .5 mi N52W, Lehigh River Bridge north of Jim Thorpe
6	U	Mauch Chunk	Broad Top, R2, .8 mi S28E, Eagle Foundry Church
7	Cu-U	Catskill	Eagles Mere, R8, .7 mi S41W, crossroads south of Beaver Lake (903')
8	Cu-U	Catskill	Laporte, R8, .45 mi N47W, Sugarloaf School
9	Cu-U	Catskill	Laporte, R8, .8 mi N15E, Sugarloaf School
10	Cu-U	Catskill	Laporte, R8, 1.05 mi N53E, Sugarloaf School
11	Cu-U	Catskill	Laporte, R8, .25 mi S76E, Sugarloaf School

TABLE 1 LOCATION OF OCCURRENCES EXAMINED* (continued)

No.	Type	Formation	Location on Quadrangle Map
12	Cu-U	Catskill	Laporte, R8, .62 mi S37E, Sugarloaf School
13	Cu-U	Catskill	Monroeton, R7, 1.5 mi S19E, Mt. Tabor Church
14	Cu-U	Catskill	Monroeton, R4, 1.5 mi S52E, Mt. Tabor Church
15	Cu-U	Catskill	Monroeton, R7, 2.1 mi S6W, Mt. Tabor Church
16	Cu-U	Catskill	Monroeton, R5, 1.1 mi S29W, USGS TT27T, 1931
17	Cu-U	Catskill	Jenningsville ($7\frac{1}{2}$), R9, .15 mi north of intersection of RT. 87 and Jenningsville road.
18	Cu-U	Catskill	Eagles Mere, R8, .4 mi S16W, crossroads south of Beaver Lake (903')
19	Cu-U	Catskill	Eagles Mere, R8, .55 mi S67W, crossroads south of Beaver Lake (903')
20	Cu-U	Catskill	Orbisonia, R2, .8 mi S33W, My. Carmel Church
21	Cu-U	Catskill	Powell, R9, 1.0 mi due south, Pleasant Valley School (at 1107')
22	Cu-U	Catskill	Monroeton, R5, .1 mi S52W, crossroads, New Era
23	U	Catskill	Mauch Chunk, R4, .6 mi S24E, Lehigh River Bridge north of Jim Thorpe
24	U	Catskill	Mauch Chunk, R4, .4 mi S20E, Penn Haven Junction
25	U	Pocono	Stoddartsville, R8, Marker 1146, Turnpike Extension, west side
26	Cu-U	Catskill	Waymart ($7\frac{1}{2}$), R8, 3 small occurrences along ridge to east of Robinson Pond - for exact location inquire locally
27	Cu	New Oxford	New Cumberland, R9, Junction of Fox Run and Eastmont-York Road (Bull Road)
28	U	Stockton	Doylestown, R6, .2 mi S27W, west tip of Hendrick Is.
29	U	Lockatong	Doylestown, R3, 2.1 mi N12W, Point Pleasant crossroads
30	U	Catskill	Huntingdon, R7, .5 mi S57E, Junction of Tatman Run and Raystown Branch

*Explanation of Coordinate System: Each 15-minute quadrangle map is divided into nine 5-minute rectangles (or $2\frac{1}{2}$-minute rectangles in the case of $7\frac{1}{2}$-minute maps), as shown below, and the occurrence is located by means of the rectangle number and a bearing and a distance from a prominent feature within the rectangle. Example: Laporte Quad., Rect. 8, 1.2 mi N20W from Branden Church is written - Laporte, R8, 1.2 mi N20W, Branden Church.

COPPER-URANIUM OCCURRENCES

General Setting

The great majority of occurrences are located in Bradford, Sullivan, Lycoming, Columbia, and Wyoming counties in the foreland region of the Appalachian Mountains of Pennsylvania. They are restricted to outcrops of the Catskill formation of Devonian age. The majority of those studied are found on the flanks of the gentle open folds in the border zone of the Allegheny Plateau (Figure 1).

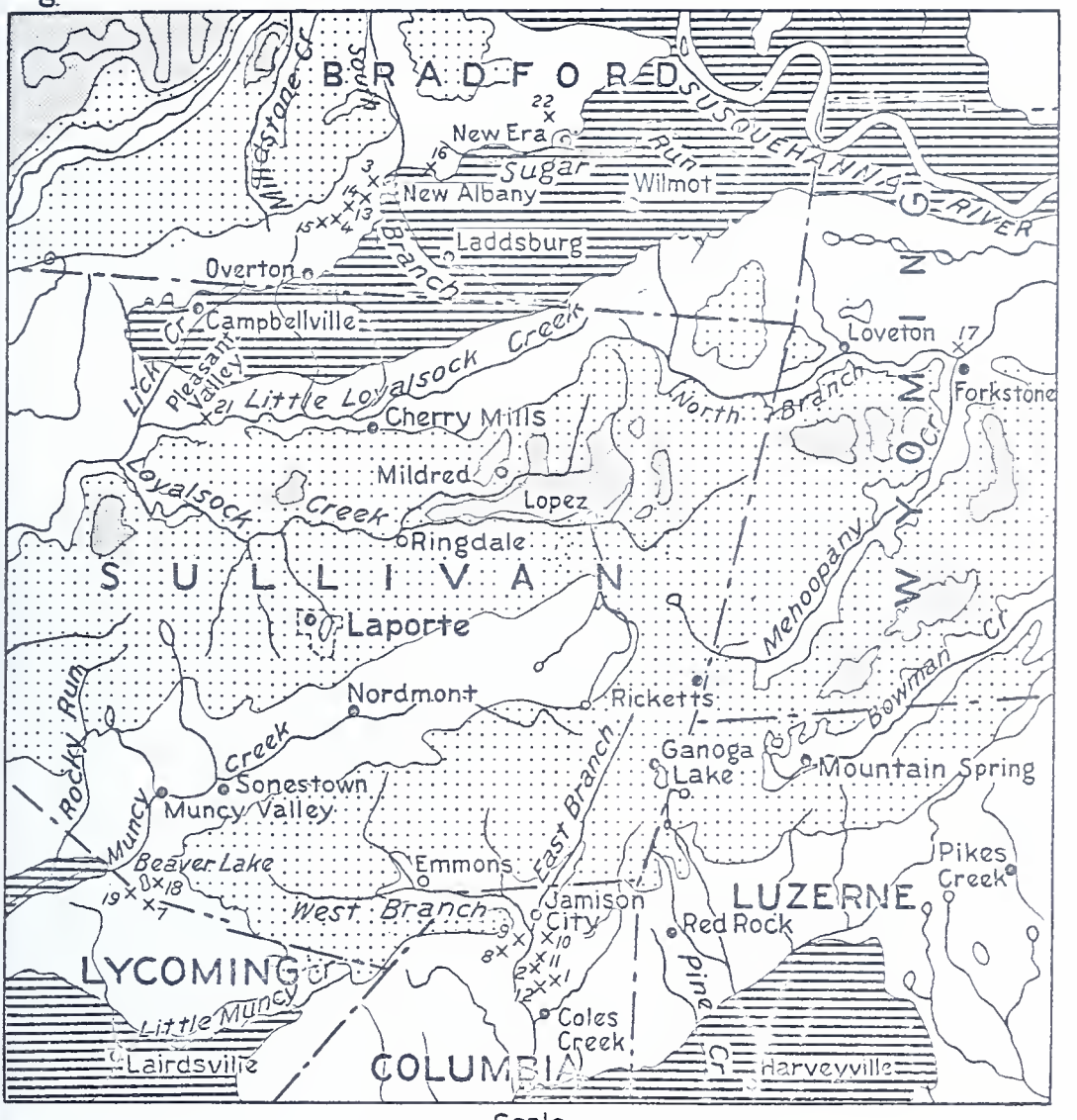
Stratigraphy

The Catskill formation comprises a thick series of continental red sandstones, shales and conglomerates. In the area studied, however, about 25 percent of the total thickness consists of gray, green, and brown sandstones, shales, and conglomerates intercalated between the red beds. The thickness of the Catskill formation ranges from about 3,000 feet in the vicinity of Jameson City to about 2,000 feet 25 miles to the north near New Albany (Figure 1). An excellent exposure of the middle and upper portions of the section can be seen along Route 487, north of the small town of Red Rock in Luzerne County.

The sediments are inferred to have been laid down as part of an enormous delta which, during the middle and late Devonian period, had its source to the southeast or east in the uplifted rocks of the ancient Acadian highlands (Barrell, 1913). Cross bedding, cut and fill structures, ripple marks, and lensing of the sandstone units are pronounced in many places. An apparent rhythmic alteration of sandstone and shale is evident in most exposures. Some type of cyclothemic deposition might be appealed to in explaining this; however, it seems to be merely the normal sequence in deltaic deposition. It is inferred that the sands were deposited within the stream channels of the delta and the shales on the broad interfluves during times of flood. Frequent shifting of the distributaries caused the lenticular sands to overlap the shale while in the former channels shales were deposited on top of the sands. At any one place, repetition of these events would give a rhythmic sandstone-shale sequence.

LOCATION OF COPPER-URANIUM OCCURRENCES

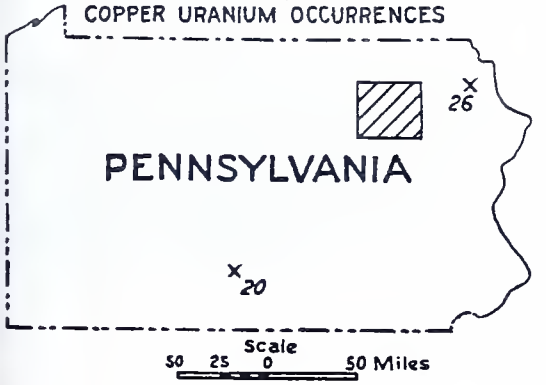
Fig. 1



Scale

6 4 2 0 6 Miles

INDEX MAP AND OTHER COPPER URANIUM OCCURRENCES



LEGEND

MISS. PENNA.
- Pottsville formation
- Pocono formation

DEVONIAN UPPER
- Catskill formation
- Chemung formation

COUNTY BDY

× Uranium prospect

○ Town

The Pocono formation of lower Mississippian age overlies the Catskill formation. It consists of massive beds of coarse gray and white sandstones and conglomerates. The base of the formation is marked by a massive sandstone conglomerate containing white to gray quartz pebbles.

Underlying the Catskill formation is the upper Devonian Chemung formation. It is a gray to brown fossiliferous sandy shale and sandstone. Its upper contact with the Catskill is hard to define and is marked by a wide transition zone where the red beds of the overlying formation intertongue with the grays and browns of the Chemung. The boundary is usually placed at the first fossiliferous horizon. This is not entirely satisfactory since, in many places, a large thickness of red beds of typical Catskill facies would be included within the Chemung.

General Features of the Occurrences

Paleostream Channels

The occurrences studied are located at varying elevations within the Catskill formation from the base up through its lower two-thirds (Figure 2). They are found in lenticular bodies, very often at the bottom of a gray or green sandstone overlying a red shale sequence. These lenses are radioactive and in many cases carry significant amounts of sulfide minerals. The rocks in the vicinity of the mineralized zones are invariably gray or green rather than red. The lens-like bodies show structural relationships with the surrounding strata which indicate that they represent parts of fossil stream channels. Localization of uranium and copper ores in this type of structure is well known in the Colorado Plateau area (McKelvey, Everhart and Garrels, 1956).

Primary Structures

Evidence of the fluvial origin of the associated sediments can be seen in such features as cross bedding, scour and fill structures, current ripple marks, thin lenses of mud pebble conglomerates and pockets of carbonaceous debris of terrestrial origin. In eight of the twenty-one occurrences studied, exposures of the above structures and the alignment of larger plant fragments permitted a rough determination of the prevailing current direction at the time of deposition. In seven of the eight cases, the direction of the current was from the southeast or east, and in one place evidence pointed to transport from the southwest. If development work results in improved exposures, a more careful analysis of the directions of the individual streams might be attempted using the method outlined by Lowell (1955).

Sediments Adjacent to Mineralized Zones

The sediments immediately surrounding the mineralized zones consist of gray to greenish sandstones and shales. The main constituents of the sandstone are subangular to rounded quartz grains. Considerable muscovite is usually present along the bedding planes. There is some feldspar, most of which is well weathered. Flacks of limonite are oriented along the bedding plane in weathered samples. Chlorite and biotite occur in minor amounts. Varying quantities of carbonaceous material are also

DIAGRAMMATIC SECTION

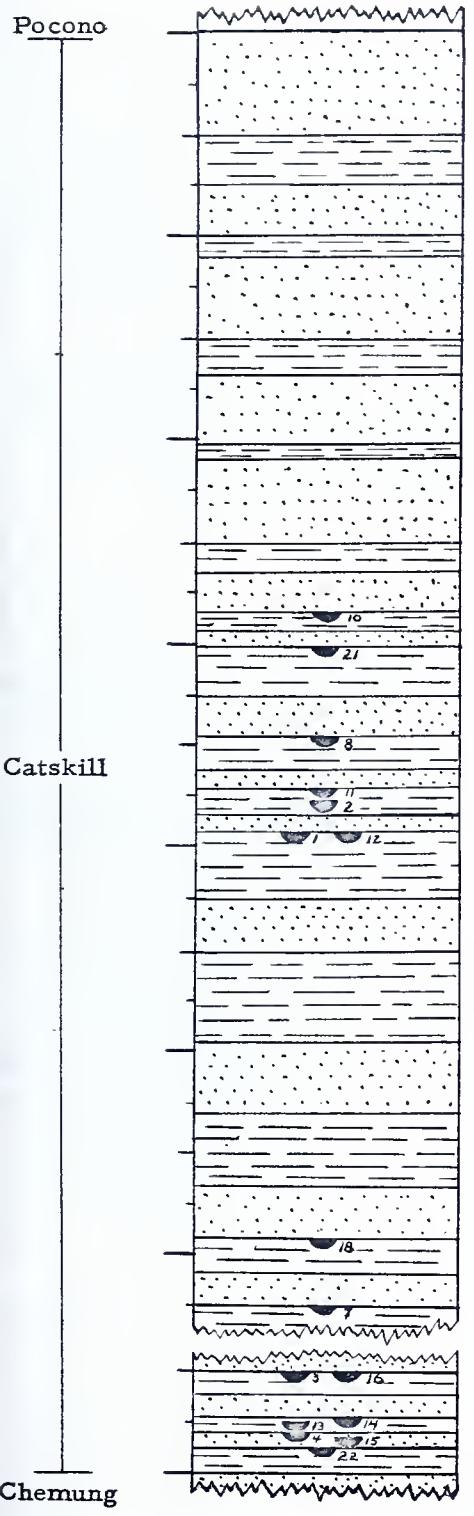


Figure 2

The section illustrates the relative positions of a number of occurrences in the Catskill formation.

The distribution of the sandstone and shale units is merely diagrammatic and should not be interpreted as representing a true section.

The occurrences above the break were measured from the Pocono, with those below it from the Chemung.

SCALE

Each division equals 100 feet.

present. The size of the fragments ranges from microscopic flakes to plant stems several feet in length.

Many of the surrounding sediments are slightly calcareous. In more than half of the occurrences a lens of calcarenite was detected in close proximity to the mineralized zone. Microscopically, these lenses are seen to be composed primarily of granular quartz, clay fragments, carbonaceous material, and calcite cement. In the field, near the ore zones they have a grayish green mottled appearance. They are not always in the same relative position at each occurrence, being either above or below the mineralized zone. In many places they can be traced by their weathered cavernous appearance for a hundred feet or so away from the mineralized zone and are seen to change color from predominantly greenish to the various shades of red of the enclosing sediments.

Red Sediments Beyond the Mineralized Zones

The red sandstones and shales that surround the gray and green sediment beyond the mineralized zones show no significant observable difference except in colo and carbon content. The sandstones are also made up of subangular to rounded quart grains along with some feldspar, biotite, chlorite and other heavy detrital minerals such as magnetite, tourmaline, and zircon. Disseminated carbon flakes are also present but in smaller quantity. Very few large fragments were seen within the red sediments. The red color of these sediments appears to be due to ferric oxide in the form of grain coatings and interstitial cement. Much of the red color could be remov from individual grains by leaching with acid.

Relation Between Color and Paleostream Channels

It has been observed that the mineralized zones are confined to gray and green rocks within what are inferred to be paleostream channels. However, these gray and green rocks do not mark the complete extent of the original channel. Away from the zones of mineralization, cross bedded and ripple marked lenses, which mu have formed an integral part of the original channel, change gradually from gray or green to red. Thus, the original channels were larger and especially wider features than the color of the rocks indicates. The gray or greenish zones appear to represe pockets within the major structure where carbonaceous material accumulated in quan ity. It may be that the original sands and shales deposited within the channels were grayish or green when originally laid down. The finer shale deposited on the inter-fluves during times of flood may have been oxidized while intermittently exposed to the air. These oxidized shales could later provide red coloring matter for the under lying coarser sediments. The infiltrating ferric oxide was effective in changing the color only in those areas where carbonaceous debris was not abundant. The reducin action of the carbon in areas of high concentration may have changed any incoming ferric iron to the ferrous form, thus preserving the original color - gray or green - and perhaps ultimately controlling the localization of the ore minerals.

Description of the Mineralized Zones

Distinctive Features

The mineralized zones are usually thin and lenticular. The average width is about one inch, a maximum of six inches having been observed in one locality (see Plate 1). In many places the zones are localized at the contact of an overlying sand lens and a tabular shale unit. This relationship was observed in sixteen of the twenty-one occurrences of this type and may also hold in some of the others at which poor exposures limited observation.

The mineralized zones are usually marked by green and locally by blue stains of copper carbonate minerals. These are localized along bedding planes and fractures in the sandstones and shales. The zones are also marked by bluish black stains of manganese minerals along bedding planes and fractures.

In one locality many thin seams of coal-like material carrying sulfide minerals and possessing considerable radioactivity were seen within a green shale unit. These seams exhibit the same splits and partings that can be seen in larger coal beds.

It should be mentioned that the majority of the occurrences examined are the partially caved or filled remains of what were originally small copper mines or prospects opened during the early part of this century. A number of long-abandoned adits and prospect pits are a common feature of the general region.

Distribution of the Radioactivity

The distribution of the radioactivity is very irregular. It ranges in magnitude from two or three times the background count up to one mr/hr in places at several occurrences. Abundant carbonaceous material is present in the form of compressed plant stems and macerated unrecognizable fragments. The material has not yet been analyzed chemically, but from the physical appearance it resembles a moderately high rank coal. Under the binocular microscope it exhibits a glossy luster and a well developed set of cleats. Conchoidal fracturing was observed on some of the material. In general, there is a relationship between the amount of carbonaceous material and the degree of radioactivity. Where the amount of coal-like material is low, the radioactivity is negligible. However, the reverse, that larger amounts of carbon mean higher radioactivity, does not always hold true. This general association of plant remains and radioactivity has been known for some time in the Colorado Plateau region.

Mineralogy and Occurrence of Uranium

The sulfide minerals that can be identified in the field are bornite and chalcocite. In many cases they are enveloped by stringers or thin bands of coaly material. Also present are chalcopyrite, marcasite, covellite, and galena. The relations between these minerals are discussed in detail later. The copper carbonates include malachite and azurite. No uranium minerals have been positively identified in any of the occurrences. The presence of uranium along with significant

A. A mineralized lens (recessed area) at the contact of a lenticular cross bedded sandstone and an underlying shale layer.

B. Galena (white) replacing carbonaceous material (gray). The dark lines are scratches on the surface of the polished section. (x 140)

amounts of barium, manganese, lead, iron, and copper has been established, however, by spectrographic analysis.

It has been mentioned that the distribution of the radioactivity within the zones of mineralization is irregular. Some of the carbonaceous material carrying sulfides is highly radioactive while on the other hand radioactivity is also noted in material not associated with sulfides. It is possible that the uranium is not present in mineral form but is held by adsorption either on other minerals (Barton and Behre, 1954) or is present as an urano-organic compound. A radiogram of a polished thin section containing carbonaceous material, chalcocite, and barite gangue, indicated that the radioactivity is distributed along the contact between the two minerals. This may represent an adsorbed film of uranium along the mineral contact and may account for the radioactivity associated with the sulfides.

Microscopic Description of the Sulfide Minerals

Carbonaceous material is present in elongated bands and irregular fragments. It is grayish tan under reflected light, anisotropic, and exhibits almost parallel extinction. The material is cut by sulfide veinlets with both matched and unmatched walls. It contains myriads of blebs of mixed sulfides which may represent fillings or replacements of small masses of resin within the coal-like material (see Plates 2 and 3).

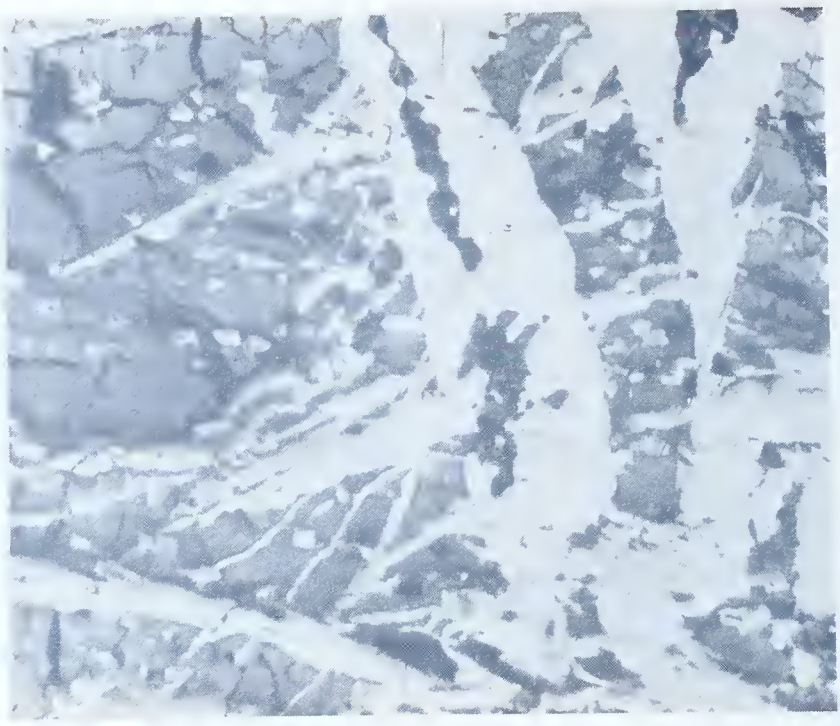
The minerals present in the polished sections studied are bornite, chalcocite, galena, chalcopyrite, marcasite, and covellite. Covellite and marcasite occur in truly minor amounts. Galena is a major constituent of one of the sections.

One of the most striking features of the sections is the preservation of plant cell structures in areas that have been almost totally replaced by sulfides. Two different types of preservation are seen. In the first, the interiors of the cells are composed of galena and the rims and cell walls of chalcocite. The original cell walls have not, in all cases, been totally replaced and in some places faint traces of the remnant material may be seen surrounding the galena of the cell interior. It appears that the galena replaced or filled the cell interiors and was later replaced along the cell boundaries by chalcocite (see Plate 4).

The interiors of the second type are made up of bornite and irregular patches of galena both of which are rimmed by cell walls of chalcocite and covellite. The sequence appears to be similar to the first type. The bornite and later the galena appear to have filled or replaced the interiors and these were later replaced along the cell boundaries by chalcocite and then covellite (see Plate 5).

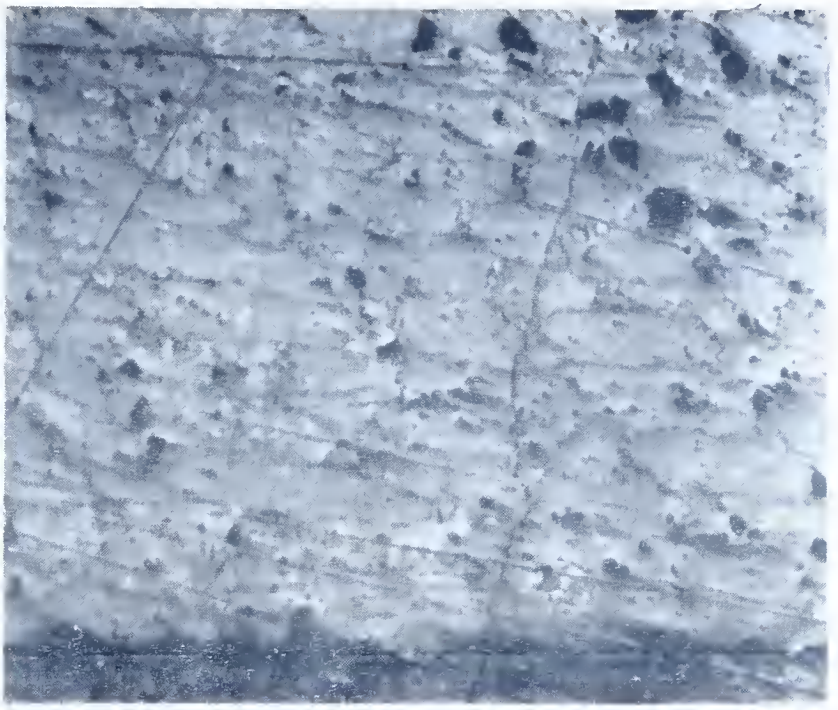
It is possible that these two types represent different stages of replacement. Bornite may have been the first mineral to fill or replace the cell interiors. It was later replaced by galena, either totally (type 1) or partially (type 2). Later, there was replacement along the cell walls by chalcocite and some covellite.

Bornite also occurs in fairly large embayed grains and small irregular masses. In most cases, they are completely surrounded by galena. These areas show

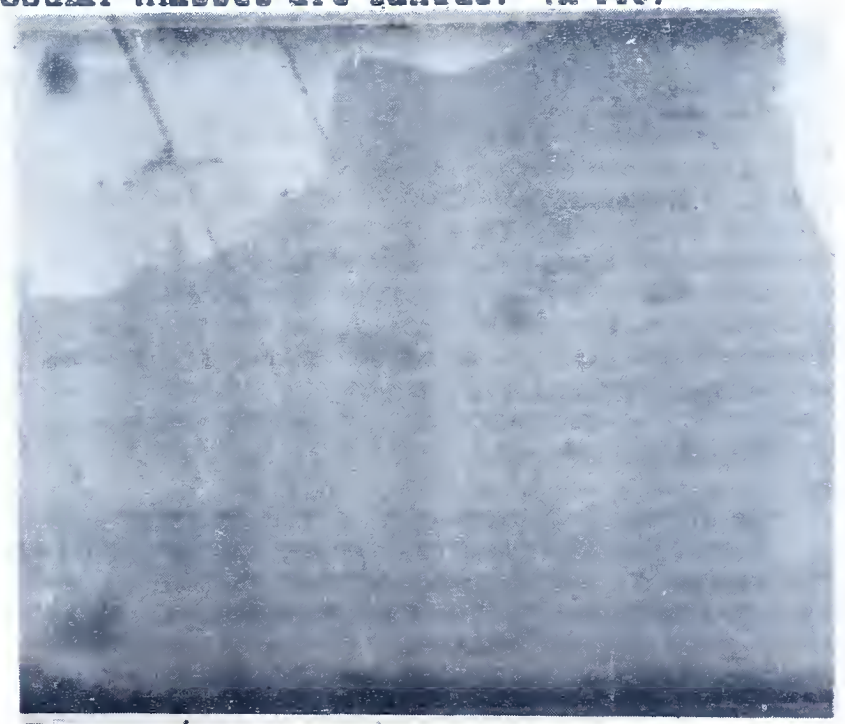


A. Showing irregular veinlets of galena replacing carbonaceous material. Also shown are blebs of various sulfides within the carbonaceous material. (x 140)

B. Cell Structures preserved by galena (light gray) and chalcocite (dark gray). (x750)



A. Cell Structures composed of bornite (gray) and irregular patches of galena (light gray). The dark rims consist of chalcocite and covellite. The dark globular masses are gangue. (x 140)



B. Bornite (dark gray) cut by chalcopyrite veinlets. Galena (light gray) also present. Dark spots are gangue. (x 750)

no remnant cell structure. Within the bornite there is, in many cases, a striking network of chalcopyrite veinlets which show only under very high power (see Plate 6). The veinlets have matched walls and exhibit three distinct orientations. The best developed set of veinlets are parallel to the bedding of the specimen, are wider, and intersect the obtuse angle between the other two. This better developed set is sometimes deformed as seen in Plate 6. The pattern cannot be related to any cleavage direction in the bornite. It appears to be a microscopic conjugate shear pattern caused by compression at right angles to the bedding. The fact that the tension crack intersects the obtuse angle (95°) and that it is crumpled and deformed can be attribute to continued stress after the formation of the fracture pattern, causing rotation of the shear planes.

The number of sections available for detailed study was limited so that further work remains to be done on the paragenesis and deformation of the ore minerals. However, the general sequence appears to be:

marcasite
bornite
chalcopyrite
galena
chalcocite
covellite

The deformation that produced the chalcopyrite veinlets followed the emplacement of the bornite and continued during the introduction of the chalcopyrite. It was of sufficient intensity to cause shearing of the bornite but not enough to seriously deform the original cell structures. A minor amount of flattening is the only deformation observed in the cells. The galena and chalcocite which appear later, on the basis of textural relations, show no evidence of having been subject to any uniform stress.

Two gangue minerals were identified. Quartz is present in euhedral crystalline form and is earlier than the sulfides. Barite is also present in irregular blebs, veinlets and sheaf-like masses that are later than the sulfides.

Structural and Stratigraphic Control

No faulting was noted in the vicinity of any of the occurrences. However, the strata immediately surrounding them are frequently cut by two well defined sets of joints which have a range in angle from about 45° to 90°. These joints do not appea to exercise any primary control on the mineralization. The fracture surfaces show n radioactivity, although in places they are stained with copper carbonates and mangane minerals, apparently oxidation products. The primary control in all cases appears to be stratigraphic.

The zone of mineralization at each locality is restricted to one horizon. Correlation is difficult due to the lenticular nature of the sediments, but in the Coles Creek region occurrences 1 and 11 can be shown to occupy the same stratigraphic position though separated 1000 feet horizontally. The exposures between the two are

ot continuous and no positive evidence of the original current direction could be ound. However, if these occurrences do represent parts of fossil stream channels, nd one is the downstream extension of the other, a zone of fairly continuous mineral- zation may exist between them. In the same general region, within an area of four quare miles, there are six other minor occurrences at varying stratigraphic eleva- ions. In general, this relationship prevails for all the occurrences studied. It is nferred that if the mineralization was not syngenetic with sedimentation, the min- eralizing solutions must have moved through a complex network of superimposed hannel deposits (Lowell, 1955). Permeability and concentration of carbonaceous naterial appear to have been the important factors in the overall localization.

Other Copper-Uranium Occurrences

Two occurrences of the same general type are found outside the area of he map in Figure 1. They are numbers 20 and 26 shown on the inset map in Figure 1. Number 26, in Wayne County is in the upper third of the Catskill formation and number 20, in Huntingdon County is near the base of the Catskill in the transition zone with he Chemung formation.

Summary

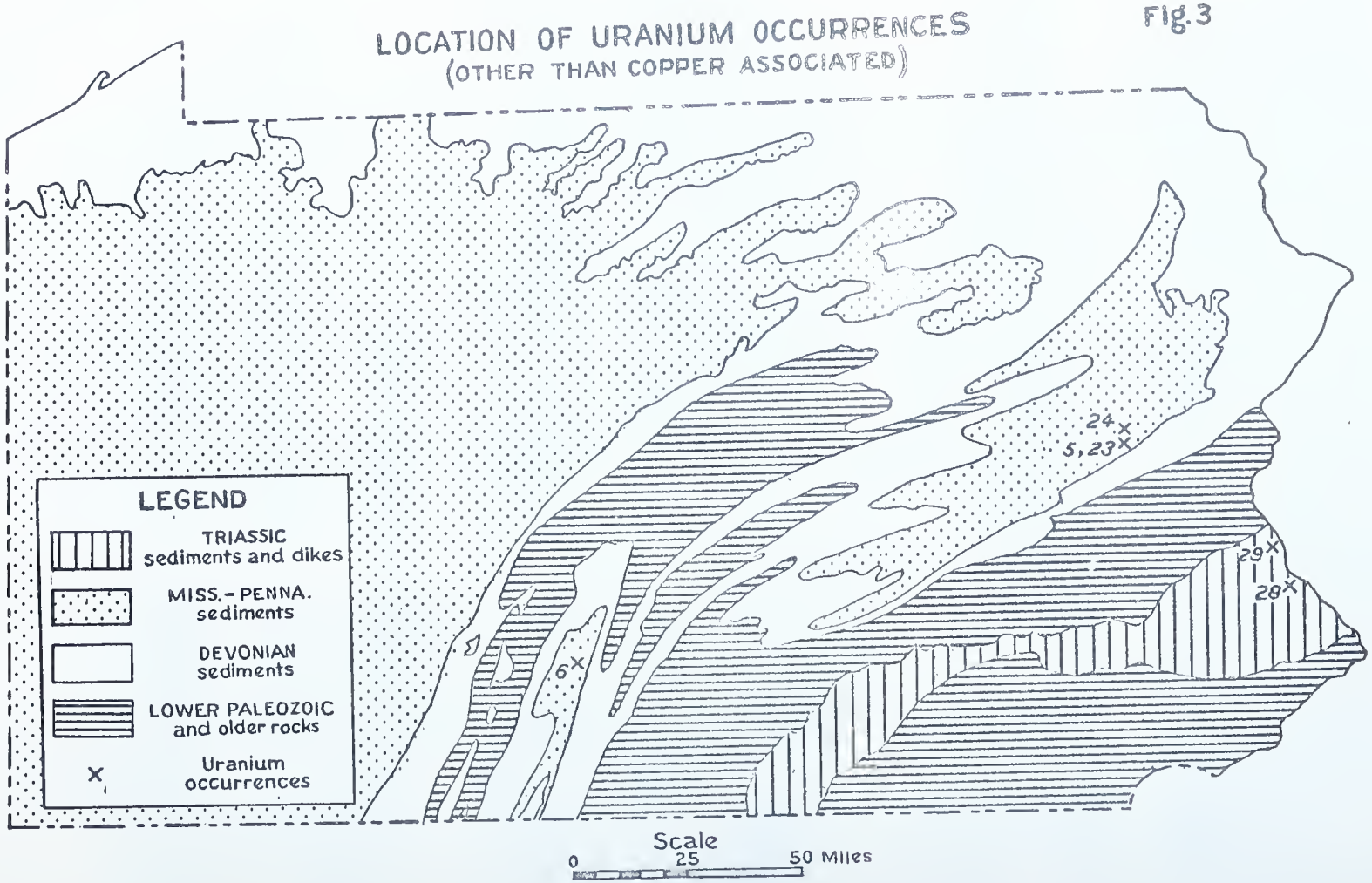
In the gently folded border zone of the Allegheny Plateau a number of copper-uranium occurrences are found in the Catskill formation of Devonian age. The radioactivity is irregularly distributed but everywhere associated with carbon- aceous material either in the form of recognizable plant fragments or of fine, dis- seminated flakes. Copper sulfides and carbonates are also common associates. In many cases the sulfides replace the coal-like material and preserve the original cell structures. No uranium minerals have been identified as yet. It is inferred that the uranium may be held by adsorption on other minerals or it may be in the form of a urano-organic compound. The occurrences are cut by joints, but the chief control appears to be stratigraphic. The mineralized zones are thin and irregular, usually occurring at the base of a sandstone lens which constitutes part of a paleostream channel. The sediments in the vicinity of the mineralized zones are gray or greenish in contrast to the predominant reds of the Catskill formation.

URANIUM OCCURRENCES
(Other than copper associated)

General Setting

These occurrences are characterized by the presence of uranium min- erals and the lack of associated copper mineralization. They occur in sedimentary lenses and paleostream channels, in rocks which range in age from Devonian to Tri- assic. The distribution of the presently known deposits of this type suggests that they are restricted to regions of more intense deformation than are the copper-uran- ium occurrences (see Figure 3).

Fig.3


LOCATION OF URANIUM OCCURRENCES
(OTHER THAN COPPER ASSOCIATED)
LEGEND
TRIASSIC sediments and dikes
MISS.- PENNA. sediments
DEVONIAN sediments
LOWER PALEOZOIC and older rocks
Uranium occurrences
24
5, 23
29
28
6
Scale
0
25
50 Miles

Occurrences in Carbon County

Four significant uranium occurrences have been reported from the vicinity of Jim Thorpe (Mauch Chunk), in the border zone between the main folded belt of the Appalachians and the relatively undisturbed Pocono Plateau. They have been described by Dyson (1954), Klemic and Baker (1954), and Montgomery (1954). Three of the four occurrences were examined briefly by this author in August, 1956. These contain uranium vanadates, carbonates, and silicates along with a "uraninite like" primary oxide. No copper minerals have been reported but a lead selenide, clausthalite, PbSe, has been identified from the Penn Haven Junction occurrence by Klemic (personal communication). According to Klemic and Baker (1954), the most important occurrence at Mt. Pisgah (#5) is found in a coarse graywacke conglomerate near the base of the Pottsville formation of Pennsylvanian age. The other three occurrences, Mauch Chunk Ridge (#23), Penn Haven Junction (#24), and Butcher Hollow are in a graywacke sandstone near the top of the Catskill formation. The mineralization is confined to lenticular bodies with high concentrations of carbonaceous material. The primary control of all four appears to be stratigraphic. Dyson, however, speaks of structural control exercised by shearing at the Mt. Pisgah occurrence. He points out that the host rock is frequently cut by shears with slickensided surfaces on which secondary uranium minerals are found. However, of the carbonaceous lenses not associated with shears, 70 percent are radioactive, usually to a high degree. He concludes that although the primary control is stratigraphic, the fractures also control the original localization to a lesser degree. While the available evidence seems to support this view, an alternative seems equally feasible upon examination of the occurrence. The control may be completely stratigraphic. The shearing associated with the regional deformation may have occurred after the mineralization. Evidence in support of this idea is that no primary oxide is distributed along the fractures themselves, but rather in some of the carbonaceous lenses cut by shears. Also, a good proportion of the total radioactivity is in non-sheared carbonaceous lenses. Of all the non-sheared carbonaceous lenses, 70 percent proved radioactive. Thus, the fractures at this occurrence may have acted only as channelways for the secondary alteration products derived from the oxidation of the primary minerals distributed in the carbonaceous lenses.

Occurrence in Huntingdon County

In Huntingdon County in central Pennsylvania there is a significant occurrence at the base of Round Knob (#6), a small outlier capped with Pottsville sandstone, on the east flank of the Broad Top Coal Basin. It is in the Mauch Chunk formation of Mississippian age, which has a thickness of about 900 feet in this region. Stratigraphically, the occurrence is about 500 feet below the overlying Pottsville Sandstone of Pennsylvanian age.

The Mauch Chunk formation in this region consists primarily of red shale, sandstone, and siltstone, with some discontinuous units that are greenish to buff in color. The beds are continental in origin and the lithology is quite similar to that of the Catskill formation. It is inferred that conditions of deposition were similar to those of Middle and Late Devonian with westward flowing streams supplying debris from the eroding Acadian Highlands, which had been subject to renewed upwarp at this time.

The occurrence consists of a composite lens of buff to grayish sandstones siltstones, and mudstones laid down in a depression that was incised in a reddish sha The lens is convex downward and slightly asymmetrical, with a width of about 100 fe A number of small elongate sandstone lenses, some of which are radioactive, are interbedded with mudstone, which makes up the major portion of the material in the structure. It is inferred that the composite lens represents the incised portion of a paleostream channel.

The mineralized lenses within the channel are reddish gray in color and contain abundant carbonaceous material in the form of large fragments and small flakes. In places where these rocks have been weathered they are reddish in color. At the edge of the channel a stringer of radioactive red siltstone containing clay galls merges into the mudstone of the main body. This zone is unusual because it represents the only truly reddish rock that exhibited significant radioactivity. The sandstones are non calcareous and are composed mainly of subangular to rounded quartz. The bedding is uneven and the mineralized rock shows bands of dark colored materia cutting across the bedding. The radioactivity occurs for the most part in the sandstone lenses, but in places adjacent to the sandstones, the mudstone is also radioact Radiometric assays made by the writer in the field, from three different locations within the structure gave U_3O_8 equivalents of .15%, .18%, and .25%. The distributi of the radioactivity along the face of the channel is irregular and ranged from a few times the background count up to 1.5 mr/hr.

There is no evidence of visible copper mineralization. Secondary yellov uranium minerals are present on some of the exposed surfaces of the lenses. They were also noted along the bedding planes and in nodular masses in some of the weathered material. This radioactive yellow mineral has been identified on the bas of chemical tests as carnotite. The dark bands cutting across the bedding were thou to contain a primary black mineral. However, examination of the heavy mineral se arates failed to disclose any material which might be uraninite or pitchblende. As i the copper-uranium occurrences, the exact mode of occurrence of the uranium, oth than as a secondary product, is not yet known and further mineralogic work will be necessary in this regard.

There is no evidence of primary structural control at this location. No obvious faulting or jointing was evident in the vicinity. However, the mudstone between the sandstone lenses is considerably sheared, and breaks into small angula blocks upon examination. The surfaces of these blocks are slickensided and are coated with manganese minerals. The radioactivity associated with the mudstone i places may be due to migration of secondary uranium minerals along these fracture This could not be verified in the field. Those sheared areas which were examined showed no evidence of secondary uranium mineralization.

Occurrences in Bucks County

These occurrences are the youngest stratigraphically of those examine They occur in the Lockatong and Stockton formations of upper Triassic age. The t occurrences examined are in sediments of very different character, one being in b argillites and the other in arkosic red beds. Both types show significant radioactiv

but no visible uranium minerals. No association with copper was noted. A copper occurrence in York County, in the New Oxford formation (#27), was examined but it exhibited no radioactivity. The New Oxford formation is a red bed sequence of upper Triassic age which has been correlated with the Stockton formation as identified farther to the east.

The occurrence in the black argillites (#29) was not studied in any detail since such occurrences are known to be rarely of economic importance and their mode of origin is fairly well accepted as being syngenetic under euxenic conditions. This occurrence is located in the Old Delaware Quarry about two miles north of the town of Point Pleasant. The zone of radioactivity is in a bed of black argillite that lies between beds of reddish argillite. The beds are exposed in the face of the old quarry. Mud cracks and ripple marks in the reddish rocks indicate shallow water deposition. The radioactivity is irregular and individual samples give very low readings.

In an abandoned quarry, opposite the west tip of Hendricks Island in the Delaware River, a significant occurrence was located (#28). The radioactive zone is within the arkosic red beds near the middle of the Stockton formation. It is one to two feet wide and is conformable with the bedding in the quarry walls for a distance of over 100 feet. The rock in the vicinity of the mineralization has a bleached look and is orange to brick red in color. It is fairly soft and weathers to a reddish clay, suggesting strongly a product of hydrothermal alteration. The arkosic beds surrounding the zone have specks of limonite distributed along the bedding planes. Even though an attempt was made to obtain fresh samples, limonite was the only substance observed. However, it is probable that the limonite was derived from pyrite that may have been disseminated throughout the rock prior to weathering. Flecks of carbonaceous matter could also be seen in these rocks.

The radioactivity throughout the zone was irregular. It ranged from an average of .15 mr/hr up to .7 mr/hr in places. There was no apparent change in lithology from place to place, but the highest counts were obtained at the contact of the zone with the barren underlying beds.

Some light gray mudstone and a badly weathered rock that has the appearance of a fresh water calcarenite were observed in the immediate vicinity of the mineralized zone. No fresh samples of this "calcarenite" could be obtained to verify its carbonate content. The surrounding beds lack cross stratification and other fluvial features. However, it is inferred that the sediments in the mineralized zone may represent a shallow lake deposit or perhaps a stream deposit which is not easily recognized because the exposure is along the channel parallel with the long axis of the stream valley.

Summary

The uranium occurrences seem to be distributed closer to areas of more intense deformation than do the copper-uranium occurrences. Whether this distribution has genetic implications and represents a regional zoning or merely reflects the lack of sufficient exposures will be a problem for further investigation in the course of this study.

These occurrences are distinguished by the presence of uranium and th lack of associated copper mineralization. They are found in sedimentary lenses, associated with carbonaceous material. Some of these lenses are inferred to be pa of paleostream channels, whereas this relationship is not clear in others.

GENESIS

Discussion of the genesis of both the copper-uranium and uranium ores will be reserved until a more complete study of the problem is made. This study include more thin and polished section study, more detailed work on the associated sediments, and the application of refined mineralogic techniques to determine the e mode of occurrence of the uranium.

ECONOMIC POTENTIAL

At several localities where the surface mineralization is of ore grade further exploration may be advisable. The surface indications at the time of this study do not indicate that any of the uranium occurrences are large enough to be mi economically under present conditions. However, until disproven by subsurface dr data, the possibility of sizable underground extensions of the mineral concentration exposed at the surface must be considered.

A very significant fact in regard to the potential of these occurrences is their structural and mineralogical similarity to the uranium occurrences at the Colorado Plateau. Many small exposures of the type seen in Pennsylvania are kno to occur in the vicinity of the larger uranium deposits of Colorado. The matter of similarity, however, should be viewed with caution, since the geologic histories of the two regions are dissimilar in many aspects.

At the present time there are different viewpoints as to the mode of ori of this type of uranium occurrence. The basic fact is that the many small occurrer do demonstrate that geological processes did exist for the concentration of uranium The same process could have created larger concentrations which require further a more thorough prospecting before being uncovered.

URANIUM ORE GUIDES AND PROSPECTING INFORMATION

A summary of the general guides which may be of aid in further prospe ing is given below.

1) Continental sediments are generally considered to be the most favor able host for this type of mineralization. The ores of the Colorado Plateau and the occurrences now known in Pennsylvania are almost exclusively in rocks of this type Continental sediments within the state that have proven favorable or that may prove to be favorable are (a) the Catskill formation, (b) the Pocono formation, (c) the Mau Chunk formation, (d) the Pottsville formation and the younger Pennsylvanian Coal Measures, and (e) the "redbed" formations of Triassic age.

2) Within the continental sediments the redbed sequences seem to hold greatest promise. However, the mineralized zones are not usually found in the beds themselves but rather in the grayish and greenish lenses which in many cases clearly represent parts of fossil stream channels. It is in these channels that carbonaceous material in the form of plant fragments and small disseminated flakes is likely to be found in abundance. This type of material should be checked for radioactivity when encountered in the field.

3) The grayish and greenish lenses often display bright green and bluish stains caused by copper carbonates. This is an easily recognized guide and is everywhere a favorable but not positive indication of the presence of radioactivity. This association holds for the great majority of occurrences in the Catskill formation and well known in many of the deposits of the Colorado Plateau. The presence of bright yellow stains on rock surfaces may indicate the presence of secondary radioactive minerals but often it may merely be due to iron staining.

4) Any outcrop of gray or greenish rocks that exhibits typical fluvial structures such as cross bedding, scouring or ripple marks should receive close examination. The mineralized zone, if present, may only be a thin stringer of radioactive sulfides or plant fragments. However, blasting or shallow drilling when feasible, may uncover a sizable deposit. Before such work is attempted, a study of the primary structures should be made, to determine, if possible, the direction of elongation and of flowage in the paleostream channel. Mineralization is most likely to extend along the length of the channel, either downstream or upstream or in both directions from the outcrop.

5) Conglomeratic zones should also receive close attention. The deposit previously described at Mt. Pisgah and many of those on the Colorado Plateau are in cases of this type. Dark colored conglomerates with high concentrations of disseminated carbon are more likely to be favorable than the lighter predominantly quartzose types.

6) The fresh water limestones or calcarenites which weather in an easily recognizable fashion may prove to be an ore guide. These limestones when weathered are brownish, soft, friable and cavernous. They have been noted in various positions in and the majority of the occurrences studied. When recognized in a continental sequence, careful examination of the surrounding strata should be made.

The two most widely used uranium prospecting instruments, the Geiger counter and the scintillometer, were found to have a somewhat restricted use in Pennsylvania. This arises from the heavy soil cover over most of the state. Even the best and most sensitive instruments are not able to detect appreciable radiation from a source that is buried under a few feet of soil. Several attempts were made to delineate the extent of one of the occurrences which was buried under only a few feet of cover. A grid survey using a scintillometer was undertaken and gave negative results. Thus, the problem of locating and outlining uranium deposits will be more difficult than it is in the Colorado Plateau where the soil cover is very thin or non-existant. Geochemical or biochemical methods might prove to be very useful in determining the extent of known deposits and for searching out others in areas where deposits have already been discovered. These methods would involve careful field work and laboratory analysis, but may prove to be a valuable tool to supplement the Geiger counter and scintillometer. One such, a biochemical method, is described by Anderson and Kurtz (1955).

BIBLIOGRAPHY

Anderson, R. Y. and Kurtz, E. B., Jr. (1955), A Biochemical Reconnaissance of the Annie Laurie Uranium Prospect, Santa Cruz County, Arizona, Econ. Geol., vol. 50, pp. 227-232.

Barrell, Joseph (1913), The Upper Devonian Delta of the Appalachian Geosyncline, Amer. Jour. Sci., 4th ser., vol. 36, pp. 429-472.

Barton, P. B. and Behre, C. H., Jr. (1954), Interpretation and Evaluation of the Uranium Occurrences near Goodsprings, Nevada, U. S. Atomic Energy Comm. Report RME 3119.

Dyson, J. L. (1954), Relation of Stratigraphy and Structure to Uranium Occurrences Near Mauch Chunk, Pennsylvania, Proc. Pa. Acad. Sci., vol. 28, pp. 124-134.

Fischer, R. P. (1956), Uranium-vanadium-copper Deposits on the Colorado Plateau, U. S. G. S. Prof. Paper 300, pp. 143-154.

Isachsen, Y. W., Mitcham, T. W. and Wood, H. B. (1955), Age and Sedimentary Environments of Uranium Host Rocks, Colorado Plateau, Econ. Geol., vol. 50, pp. 127-134.

Klemic, Harry and Baker, R. C. (1954), Occurrences of Uranium in Carbon County, Pennsylvania, U. S. Geol. Survey Circular 350.

Lowell, J. D. (1955), Applications of Cross Stratification Studies to Problems of Uranium Exploration, Chuska Mountains, Arizona, Econ. Geol., vol. 50, pp. 177-185.

McKelvey, V. E., Everhart, D. L. and Garrels, R. M. (1956), Origin of Uranium Deposits, Econ. Geol., 50th Ann. Vol., Pt. 1, pp. 492-510.

Miller, L. J. (1955), Uranium Ore Controls of the Happy Jack Deposit, San Juan County, Utah, Econ. Geol., vol. 50, pp. 156-169.

Mitcham, T. W. and Evensen, C. G. (1955), Uranium Ore Guides, Monument Valley District, Arizona, Econ. Geol., vol. 50, pp. 170-176.

Montgomery, Arthur (1954), Uranium Minerals of the Mauch Chunk Area, Pennsylvania, Pa. Acad. Sci., Proc., vol. 28, pp. 102-110.

Willard, Bradford (1936), Continental Upper Devonian of Northeast Pennsylvania, Bull. Geol. Soc., Amer., vol. 47, pp. 565-607.

Wright, R. J. (1955), Ore Controls in Sandstone Uranium Deposits of the Colorado Plateau, Econ. Geol., vol. 50, pp. 135-155.